IMPROVIMG CROP WATER PRODUCTIVITY IN IRRIGATED AGRICULTURE: A REVISIT

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ABSTRACT

Globally, the irrigated agriculture constitutes approximately 17% of total cultivated farmland, consumes about four fifths of the total available freshwater and produces nearly 40% of total food and fiber production. But the access of irrigated agriculture to the scarce water resource is under sever threat, because of the increasing water needs due to rapid urbanization, environmental consciousness, recreation and tourism. Recently, the United Nations in its report have estimated that increased cropping intensity to meet world food needs will require an increase of 40% in the area of harvest crops by 2030, and that the amount of water allocated to irrigated agriculture must increase correspondingly by 14%. However, it not at all assured that the needed water will be available by that time. Further, due to global climate change there will be increased uncertainty on temperatures, annual precipitation levels, and regional rainfall distribution patterns leading to variation in spatial and temporal availability of water and also hange in the pattern of crop evapo-transpiration (ET). Hence, the pressure on water resources will be alarming and irrigated agriculture being the largest consumer of available fresh water, there will be economic and social pressures on all water users to reduce irrigation water amounts.

Hence the only option left is to improve the productivity of water through minimization of water losses which includes redesigning total irrigation systems for higher efficiency, successfully treating and reusing degraded waters, reducing evaporation losses, introducing site-specific water applications, implementing managed-deficit irrigations, and

employing engineering techniques to minimize leaching. The productivity of water through management of soil water can be raised more beneficially than with genetic approaches (biotechnology and breeding). Scientific irrigation scheduling has the potential to improve the ratio of yield to consumptive use because of the optimized quantity and timing of water applications. Use of carefully managed deficit irrigation strategies can provide the greatest potential for substantially reducing agricultural water use. Geographically relocating certain crops to their most productive areas and cultivation of high value and early mature crops may remarkably reduce water consumption. Furthermore, advanced irrigation technologies, precision agriculture tools and state-of-the-art delivery systems if fully implemented for successful deficit irrigation management using site-specific technologies have a potential to bring down the water need to the order of 15% to 30%.

Keywords: Irrigated Agriculture, Water Use Efficiency, Advanced Irrigation Technology, Irrigation Management, Site Specific Irrigation, Crop Water Productivity

1. INTRODUCTION

Globally the irrigated agriculture constitutes approximately 17% of total cultivated farmland, consumes about four fifths of the total available freshwater and produces nearly 40% of total food and fiber production (Evans and Sadler, 2008). However, the access of irrigated agriculture to the scarce water resource is under sever threat, because of the increasing water needs due to rapid urbanization, environmental consciousness, recreation and tourism. Recently, the United Nations in its report (U.N.E.S.C.O, 2006) have estimated that increased cropping intensity to meet world food needs will require an increase of 40% in the area of harvest crops by 2030, and that the amount of water allocated to irrigated agriculture must increase correspondingly by 14%. However, it not assured that the needed water will be available by that time.

Further, due to global climate change there will be increased uncertainty on temperatures, annual precipitation levels, and regional rainfall distribution patterns leading to variation in spatial and temporal availability of water and also change in the pattern of crop evapo-transpiration (ET). It is due to the above facts, the pressure on water resources will be alarming and irrigated agriculture being the largest consumer of available fresh water, there will be economic and social pressures on all water users to reduce irrigation water amounts.

In the above context, it is the crucial time for water resources engineers and scientists to seriously search novel approaches for irrigation water management and systems are needed to address the declining land base and water allocations to balance production needs. Hence in the present study it is attempted to review various concepts of water use efficiency (WUE) to improve water productivity and methods needed to improve water productivity in irrigated agriculture to meet the food and fiber needs of growing population.

2. CONCEPTS AND DEFINITIONS OF WUE AND CROP WATER PRODUCTIVITY

The term productivity is measured by the amount of any given resources that must be expended to produce one unit of any goods or services. Hence, the water productivity is measured by the volume of water supplied to the unit area of cropped field to produce a unit output. Improving water productivity also deals with improving WUE which means using water strategically for crop production while maintaining or even increasing total crop productivity through improved management and advanced irrigation technologies.

So far as the crop water productivity is concerned, it is basically defined as an input/output ratio to measure productivity. In other words it is also defined as the crop productivity per unit volume of water used. Though many different definitions of crop water productivity have been offered by large number scientists, it is generally considered as the ratio of the harvested biomass to the water consumed to achieve that yield (Steduto, 1996). Burt et al. (1997) presented a comprehensive discussion on the definitions of various efficiencies and uniformity measures related to irrigation. Bau (1991) explained efficient water use consists in optimizing water use. According to Viets (1962), WUE is the yield of interest (e.g., grain, biomass) divided by the water used to produce that yield. Bos (1980) suggested WUE as the yield benefit from irrigation divided by the irrigation water applied.

3. METHODS TO IMPROVE CROP WATER PRODUCTIVITY

Various strategies to minimize water loss include redesigning total irrigation systems for higher efficiency, successfully treating and reusing degraded waters, reducing evaporation losses, introducing site-specific water applications, implementing managed-deficit irrigations, and employing engineering techniques to minimize leaching

3.1 Improving Management Capacity

The productivity of water in irrigated agriculture can be raised through management of soil water and selection of most appropriate irrigation timing to minimize the negative effects of water deficits on yields and quality. Maximization of the productivity of water by managing soil water can be achieved through proper design of water delivery and farm irrigation system for application of required amount of water at the right time with an eye on the optimal use of available rain water. Further, management of irrigation water under severe to moderate soil water deficit conditions during the growing period of crops can increase crop productivity while reducing the amount of water applied. This implies economically optimization of production for each unit of water used can maximize crop productivity while reducing the amount of water applied.

Hence it is clear that properly managed deficit irrigation strategies can reduce agricultural and urban water use and conserve water to an appreciable extent, however it needs excellent control of the timing and amounts of the applied water.

3.2 Crop Selection

In arid and semiarid areas where there is scarcity of water resulting in frequent partial season droughts, crops that mature more quickly, such as small grains, cool season oil seeds (e.g., mustards, camelina), or various pulse crops such as peas and lentils are advisable. Shifts to deep rooted, drought resistant crops such as sunflower and safflower may maximize use of precipitation water stored in the soil. However, longer season crops such as maize (corn) may have reduced yields.

3.3 Scientific Irrigation Scheduling Practice

Scientific irrigation scheduling refers to application of optimum quantity of water at most appropriate time so that crop stress and over-application is avoided. It improves the ratio of yield to consumptive use (water productivity), primarily because of improved timing of water applications. However, it is always essential to combine the effects of scheduling of irrigation with improved farm practices. The irrigation scheduling can be further improved by converting irrigation system from gravity surface irrigation to pressurized drip or sprinkler systems.

3.4 Supplemental Irrigation practice

Supplemental irrigation complements reasonably sufficient rainfall and stabilizes production despite short-term droughts. However, this practice is important primarily in arid and semiarid areas where it becomes possible to apply only one or two irrigations per season. This is a form of managed deficit irrigation where the impact of the timing and applications of limited water supplies relative to only rain-fed agriculture can be very positive (Sojka et al, 1981). These techniques imply applying water during critical growth stages so that there is optimal benefit per unit volume of water per unit quantity of crops of interest produced.

3.5 Spatially Optimizing Production

Geographically relocating certain crops to their most productive areas and soils, thereby minimizing irrigation amounts and maximizing overall efficiencies (spatial optimization) creates an option for improving the productivity of water. Relocating specified crops to climatic regions and soil types that best suits to maximal output would be the most economically efficient use of resources.

3.6 Use of Advanced Irrigation Techniques

Almost every aspect of irrigation has seen significant innovation, including diversion works, pumping, filtration, conveyance, distribution, application methods, drainage, power sources, scheduling, erosion control, land grading, soil water measurement, and water conservation etc.. Originally, irrigation was accomplished by methods utilizing gravity to distribute and apply water. Now sprinkler technology is considered as the most acceptable alternative to gravity irrigation in water scarce areas. High-frequency drip irrigation and other micro irrigation methods have shown to increase the yield and quality of fruit and vegetable crops through reduced water and nutrient stresses. Tied to an effective soil water monitoring program, good design, and appropriate management practices, micro irrigation can have an application efficiency of 95% or more without drought stress, and is now used on about 5% of the irrigated area in the United States (NASS, 2002). Similarly, a modification of self-propelled sprinkler irrigation systems termed low-energy precision applications (LEPA) has been found to be more than 95% efficient in field situations (Evans and Sadler, 2008).

3.7 Use of Improved Irrigation Systems

The most important reasons to go for system improvements are to reduce labor by automation, minimizing water costs by conservation (higher irrigation efficiencies) and expanding irrigated area with the diverted water volume (irrigation capacity). Further, there are several management options for reducing water losses. Making small pits or basins (mini reservoirs), commonly called furrow diking, in sprinkler irrigated fields to hold water becomes beneficial. Irrigation at night can reduce evaporation losses.

Weeds are major non beneficial consumers of water and their control is important to maximize WUE. However, use of chemical to control weeds appear costly and may have unwanted environmental consequences. Use of mulches for weed control may reduce non beneficial evapo-transpiration and soil evaporation.

Reduced tillage techniques can reduce soil evaporation losses. Drip irrigation technologies can conserve water by greatly reducing soil evaporation and maximizing crop water productivity. These strategies could also incorporate alternative cropping systems including winter crops and deep rooted crops that maximize use of stored soil water and some nutrients.

3.8 Site-Specific Irrigation

Site specific technology to maximize crop yield per unit volume of water have a great potential in arid and semi arid regions. Experiments show that potential water savings under non stress conditions (maximum yield) using site-specific technologies are probably on the order of about 5% or less, but can be increased up to about 15% to 30% [Sadler et al., 2005]. By aligning irrigation water application with variable water requirements in the field, total water diversions may be reduced and, almost certainly, deep percolation and surface run off can be reduced.

3.9 Micro irrigation

Micro irrigation is an extremely flexible irrigation method and has the potential for appreciable water savings because of precise, high-level management practices. Due to its high cost and intensive management requirement currently its use is restricted to relatively small fields. However, this method can be applied to almost all cropping situation, climatic zone and over a wide range of terrain. This type of irrigation has a greater potential where soils are of very low or very high infiltration rates and salt affected soils. But micro irrigation is used on less than 1% of lands worldwide, primarily because of its recent development and high initial capital cost. Micro irrigation can be used on most agricultural crops, although it is most often used with high-value specialty crops such as vegetables, ornamentals, vines, berries, olives, avocados, nuts, fruit crops, and greenhouse plants because of its relatively high cost and management requirements. The use of micro irrigation is increasing around the world, and it is expected to continue to be a viable irrigation method for agricultural production in the near future. With increasing demands on limited water resources and the need to minimize environmental consequences of irrigation, this technology will undoubtedly play an important role in the future irrigation scenario.

4. CONCLUSIONS

Due to the fact that irrigated agriculture contributes nearly 40% of total food and fiber production worldwide, and irrigated land base and available fresh water is declining day by day, there is an acute need to maximize production per unit volume of water supplied per unit area of cropped field. To maximize production per unit volume water (maximization of crop water production), all the components of irrigated agriculture responsible for improving water productivity (management of soil water and irrigation timing, appropriate crop selection, supplemental irrigation during critical growth stage, use of advanced irrigation techniques and improved irrigation systems and site specific irrigation etc.) on a specific zone level can be integrated and the whole system can be optimized.

Use of advanced irrigation technologies, precision agriculture tools and state-of-the-art delivery systems, if fully implemented for successful deficit irrigation management, can increase WUE to an appreciable extent. Further, water savings under non stress conditions (maximum yield) using site-specific technologies have a potential to bring down the water need to the order of 15% to 30%.

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